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THE LIMITED AMOUNT of level tillable land in West Virginia often makes it desirable to use short rotations. Corn and soybeans are commonly used because these crops furnish the kind of feed needed for livestock. In such a rotation crops occupy the land less than one-half of the year. During the winter months there is a considerable loss of nutrients by leaching and erosion. The growing of cover crops to furnish vegetative cover reduces losses, and plowing these under as green manures has a beneficial effect on the soil.

The experiment reported here was started in order to determine the value of different cover crops in increasing crop yield. Before discussing the results it should be emphasized that on the level land used for the experiment, little effect could be expected from the reduction of losses by erosion — the effect measured being accomplished principally by the reduction of loss by leaching, the addition of nitrogen by certain cover crops, the increase in the availability of plant nutrients, and the addition of organic matter.

Experimental Procedure

In the spring of 1921 forty-eight* plots 18 feet wide and 136 feet long were laid out on a fairly level area of Dekalb silt loam soil on the Dairy Husbandry farm near Morgantown.

These plots were cropped uniformly to soybeans in 1921 and to cover crops planted in the fall after the removal of the soybeans. From 1922 to 1934 a two-year rotation was followed of corn and soybeans with and without cover crops. The corn was harvested at the proper time for silage and the soybeans were harvested for hay when the pods were

PLAN OF EXPERIMENT

Plot Numbers		Cover crop
Series 1	Series 2	
1-7-13-19	25-31-37-43	None
2-8-14-20	26-32-38-44	Rye
3-9-15-21	27-33-39-45	Rye and vetch
4-10-16-22	28-34-40-46	Vetch
5-11-17-23	29-35-41-47	Crimson clover
6-12-18-24	30-36-42-48	Sweet clover

*The writers are indebted to Dr. T. E. Odland for helping to plan and conduct the experiment for the first eight years.

approximately one-half filled. These crops were dried to about 2% moisture and the yields calculated on the basis of silage containing 75% water and soybean hay containing 15% water.

The cover crops grown as shown in the accompanying plan consisted of rye, rye-and-vetch, vetch, crimson clover, and sweet clover. These were seeded on the corn plots at the time of the last cultivation and on soybean plots as soon as possible after the hay was removed. No fertilizer was used during the first nine years of the experiment, but in 1929 and in each succeeding year superphosphate was applied to all plots at the rate of 300 lbs. per acre. In 1931 samples of the soil showed a lime requirement of two tons per acre. Lime was applied uniformly to all plots to correct this acidity. No other manure or fertilizer was applied.

Results

The effect of cover crops on the yield of crops following is determined to a considerable extent by the amount of growth made by the cover crop. While no data on actual weights were obtained, stand notes were taken each spring and these give a general idea of the value of the crop in preventing leaching and in adding organic matter. The percentage average stands are as follows:

	Rye	Rye and vetch	Vetch	Crimson clover	Sweet clover
After corn	49.2	44.4	9.8	8.4	6.8
After soybeans	91.2	81.2	61.2	10.2	5.4

The rye and the rye-and-vetch plots did not differ greatly. During the last few years the stand and growth of the rye-and-vetch plots were slightly superior to the rye plots. Vetch gave fairly good growth following soybeans, but little when planted in corn at the last cultivation. Few plants of crimson clover and sweet clover survived the winter. These were badly heaved and made little growth in the spring. Actually the amount of growth turned under was little more than that on the check plots, which had some weed growth. In considering the data on the effect of cover crops, therefore, it should be remembered that only small amounts of crimson clover and sweet clover were plowed under. These would not be expected to show much effect on crop yield under the conditions of the experiment.

The yields of corn following the different cover crops are given in Table 1. Each value represents the average of the four plots for each year.

Considering first the average yields for the entire period it is evident that there has been a slight increase in yield following rye, rye-and-vetch, and vetch cover crops, and apparently a decrease in yield following crimson clover and sweet clover. In order to determine whether these differences were due to plot variation or to the effect of the cover crop, the data were analyzed statistically with results as shown in Table 2. Inasmuch as it appeared that there might be a residual effect, the analysis was divided into three parts: (1) analysis of results from 1922-1928, (2) analysis of results from 1929-1934, and (3) analysis of results of the 13 years. The methods used in making the analyses are given in the appendix (page 10).

TABLE 1—*Yield of corn silage following various cover crops (Average of 4 plots)*

Year	Series	Yield of corn silage following					
		Check	Rye	Rye & vetch	Vetch	Crimson clover	Sweet clover
		tons	tons	tons	tons	tons	tons
1922	2	10.27	9.80	9.31	9.93	10.28	10.75
1923	1	14.99	15.67	13.25	14.19	13.93	13.52
1924	2	5.21	4.87	5.80	5.76	4.76	5.64
1925	1	14.50	14.57	12.34	16.21	14.88	14.14
1926	2	8.59	10.53	10.07	9.19	9.28	10.19
1927	1	4.37	3.44	3.64	3.22	3.69	3.28
1928	2	11.14	12.44	10.58	12.31	10.19	10.25
1929	1	5.19	6.49	7.33	6.00	5.57	7.02
1930	2	5.61	5.90	7.03	5.68	5.41	4.12
1931	1	12.40	14.13	13.81	12.68	12.94	11.72
1932	2	8.86	9.26	10.18	9.63	9.49	8.43
1933	1	9.60	10.68	11.54	11.05	9.97	10.52
1934	2	12.88	13.38	11.82	10.50	11.54	10.89
Ave. 1922-1934		9.51	10.08	9.75	9.71	9.28	9.24
Ave. 1922-1928		9.87	10.19	9.28	10.12	9.57	9.68
Ave. 1929-1934		9.09	9.97	10.29	9.26	8.96	8.78

Table 2 shows the results and their interpretation by Student's *(1)* method. It will be seen that by Method I the increases or decreases in yield of corn silage on plots having cover crops were too small to be significant during the period 1922-1928, but that the plot having rye gave 0.904 tons per acre more silage than the plot having rye-and-vetch as cover crop. During the last six years rye increased the yield 0.853 tons per acre and rye-and-vetch 1.192 tons per acre over the yield of the check plots. These two cover crops were the only ones which gave yields significantly different from the check. During this period rye was no better than rye-and-vetch. Over the 13-year period only rye gave significantly better yields of corn silage than did the check plot.

(1) "Student" The Probable Error of a Mean. Biometrika 6:1-257. 1908.

Inasmuch as the yield data showed that in general the check plots were higher-yielding during the early part of the experiment, a second analysis was made using the first crop of corn in each series as a basis for evaluating the effect of various cover crops. By this method of analysis (Method II) the differences in yields and their significance are also shown in Table 2 (page 6).

TABLE 3—*Yield of soybean hay following various cover crops (Average of 4 plots)*

Year	Series	Yield of soybean hay following					
		Check	Rye	Rye & vetch	Vetch	Crimson clover	Sweet clover
		tons	tons	tons	tons	tons	tons
1921	1	1.65	1.81	1.68	1.62	1.65	1.71
1921	2	2.36	2.21	2.22	2.38	2.32	2.44
1922	1	1.82	1.82	2.31	2.11	1.89	1.84
1923	2	1.86	2.03	2.02	2.05	1.99	2.11
1924	1	1.79	1.94	1.95	1.90	1.90	1.68
1925	2	1.72	1.82	1.84	2.06	2.03	1.75
1926	1	1.91	2.32	2.13	2.04	1.94	1.98
1927	2	1.30	1.49	1.51	1.39	1.38	1.39
1928	1	1.72	2.09	2.05	2.14	2.01	1.88
1929	2	1.71	2.23	2.14	1.94	1.75	1.84
1930	1	1.77	2.16	2.20	2.12	1.95	1.91
1931	2	2.54	3.12	3.20	2.69	2.64	2.85
1932	1	2.19	2.83	2.88	2.74	2.61	2.60
1933	2	2.63	2.68	2.58	2.64	2.46	2.45
1934	1	1.82	2.03	2.05	1.98	1.94	1.96
Ave. 1922-1934		1.91	2.20	2.22	2.14	2.04	2.02
Ave. 1922-1928		1.73	1.93	1.97	1.96	1.88	1.80
Ave. 1929-1934		2.11	2.51	2.51	2.35	2.23	2.27

It will be seen that this method of analysis shows a more beneficial effect from cover cropping. During the first period the increases in yield of corn silage over that of the check plots varied from 0.269 tons per acre for crimson clover to 1.405 tons per acre for vetch. The increases of 0.996 tons per acre for rye and vetch and 1.405 tons per acre for vetch were found to be significant. The smaller increases on the other plots were within the limits of plot variation. During the last six years of the experiment the increases were usually greater, varying from 0.494 to 2.542 tons per acre. All the plots except the ones having sweet clover were significantly better than the check plots, and the rye-and-vetch plot produced 1.763 tons per acre more corn silage than the rye plots. The average results over the 11-year period show increased yield, which is significant in all cases except on the sweet clover plots.

The effect of the various cover crops on the yield of soybeans is shown in Table 3. The generally low yields obtained were undoubtedly due to the fact that no fertilizers were applied during the early years of the experiment. It will be noted that the yields for the later years were higher, probably because of the use of superphosphate and lime on all plots. It will also be noted that the average yields for the entire

TABLE 2—*Analysis of corn-silage yield following various cover crops*

METHOD I

Comparison	1922-1928			1929-1934			1922-1934		
	D[1]	P	Interpretation	D[1]	P	Interpretation	D[1]	P	Interpretation
Check vs. rye	.321	0.3-0.2	No difference	.883	<0.01	Rye better	.581	<0.01	Rye better
Check vs. rye & v.	—.583	0.1-0.05	No difference	1.192	<0.01	Rye & v. better	.236	0.4-0.3	No difference
Check vs. vetch	.379	0.5-0.4	No difference	.327	0.6-0.5	No difference	.355	0.3-0.2	No difference
Check vs. c. clov.	—.211	0.5-0.4	No difference	.342	0.4-0.3	No difference	.044	0.9-0.8	No difference
Check vs. s. clov.	—.061	0.9-0.8	No difference	—.058	0.9-0.8	No difference	—.059	0.9-0.8	No difference
Rye vs. rye & vch.	—.904	<0.01	Rye better	.308	0.5-0.4	No difference	—.345	0.2-0.1	No difference

METHOD II

Comparison	1924-1928			1929-1934			1924-1934		
	D[1]	P	Interpretation	D[1]	P	Interpretation	D[1]	P	Interpretation
Check vs. rye	.418	0.4-0.3	No difference	.778	<0.01	Rye better	.615	0.02-0.01	Rye better
Check vs. rye & v.	.006	0.02-0.01	Rye & v. better	2.542	<0.01	Rye & v. better	1.839	<0.01	R. & v. better
Check vs. vetch	1.405	<0.01	Vetch better	.973	0.05-0.02	Vetch better	1.169	<0.01	Vetch better
Check vs. c. clov.	.269	0.04-0.3	No difference	.736	0.02-0.01	C. cl. better	.524	0.05-0.02	C. cl. better
Check vs. s. clov.	.592	0.2-0.1	No difference	.494	0.3-0.2	No difference	.539	0.10-0.05	No difference
Rye vs. rye & vch.	.578	0.2-0.1	No difference	1.763	<0.01	Rye & v. better	1.224	<0.01	R. & v. better

[1]D is the increase in yield in tons over check plot or rye plot in rye—rye-and-vetch comparison.

period of the experiment were higher in the areas having a cover crop and that rye, rye-and-vetch, and vetch gave the greatest increases. This is in accord with the yield of corn reported in Table 1. The data were analyzed by the same methods used for corn, and the results of the analysis are given in Table 4 (page 8).

The results from the use of Method I show that the increases are significant for rye, rye-and-vetch, and vetch of 0.201, 0.241, and 0.186 tons per acre respectively during the period 1922-28. For the last six years and for the 13-year period all the cover crop plots yielded significantly higher than the check plot. The mixture of rye-and-vetch was no better than rye. Since soybeans are legumes capable of taking a part of their nitrogen from the air, the additional nitrogen added on the rye-and-vetch plots had no effect. By using the first crop on each plot as a measure of the natural productivity of the soil, the results are similar for the rye, rye-and-vetch, and vetch cover crops, but they show that the increases due to crimson clover and sweet clover were not large enough to be considered significant and that the mixture of rye-and-vetch was no better than rye alone. By this method the differences in yield of soybeans were usually smaller than by Method I. However, they are probably more reliable since the original productivity of the soil is considered.

Nitrogen Content of the Soil

Inasmuch as one of the benefits usually attributed to the use of cover crops as green manures lies in their ability to conserve soil nitrogen, the soil was analyzed at the beginning and end of the experiment to determine how effective the cover crops had been. The results for Series 1 are given in Table 5.

Table 5—*Nitrogen content of soils (Series 1)*

Treatment	Average percent nitrogen		Difference
	1921	1934	
Check	.133	.100	—.033
Rye	.140	.109	—.031
Rye and vetch	.140	.112	—.028
Vetch	.140	.109	—.031
Crimson clover	.142	.105	—.037
Sweet clover	.142	.105	—.037

It will be noted that for each treatment the average nitrogen content of the soil showed a decided decrease in the 13 years. This was true of all plots in the series tested. The difference in loss of nitrogen between the plots having cover crops and the check plot was too small to be significant. A part of the loss of nitrogen may be attributed to

TABLE 4—*Analysis of soybean yields following various cover crops*

METHOD I

Comparison	1922-1928			1929-1934			1922-1934		
	D[1]	P	Interpretation	D[1]	P	Interpretation	D[1]	P	Interpretation
Check vs. rye	0.201	<0.01	Rye better	0.402	<0.01	Rye better	0.294	<0.01	Rye better
Check vs. rye & v.	0.241	<0.01	R. & v. better	0.397	<0.01	R. & v. better	0.313	<0.01	R. & v. better
Check vs. vetch	0.186	0.02-0.01	Vetch better	0.274	<0.01	Vetch better	0.226	<0.01	Vetch better
Check vs. c. clover	0.059	0.3-0.2	No difference	0.209	0.05-0.02	C. clov. better	0.128	0.02-0.01	C. clov. better
Check vs. s. clover	0.058	0.3-0.2	No difference	0.237	0.02-0.01	S. clov. better	0.141	<0.01	S. clov. better
Rye vs. rye & vch.	0.040	0.5-0.4	No difference	—.005	>0.9	No difference	0.019	0.9-0.8	No difference

METHOD II

Comparison	1922-1928			1929-1934			1922-1934		
	D[1]	P	Interpretation	D[1]	P	Interpretation	D[1]	P	Interpretation
Check vs. rye	0.174	<0.01	Rye better	0.393	<0.01	Rye better	0.275	<0.01	Rye better
Check vs. rye & v.	0.281	<0.01	R. & v. better	0.451	<0.01	R. & v. better	0.359	<0.01	R. & v. better
Check vs. vetch	0.158	0.05-0.02	Vetch better	0.225	0.02	Vetch better	0.189	<0.01	Vetch better
Check vs. c. clov.	—.059	0.4-0.3	No difference	0.077	0.4-0.3	No difference	0.004	>0.9	No difference
Check vs. s. clov.	—.055	0.4-0.3	No difference	0.113	0.2-0.1	No difference	0.026	0.7-0.6	No difference
Rye vs. rye & vch.	0.108	0.2-0.1	No difference	0.054	0.4-0.3	No difference	0.083	0.1-0.05	No difference

[1]D is the increase in yield in tons per acre over check plot or over rye plot in rye—rye-and-vetch comparison.

sampling. However, differences due to sampling should be the same in each plot. It may be considered, therefore, that the loss of nitrogen from the soil was about the same regardless of whether the nitrogen disappeared by leaching or by crop removal. The amount of nitrogen added in the leguminous cover crops was apparently no greater than the amount needed by the increased yield of crops. The effect of cover crops was, therefore, to furnish more available nitrogen for the succeeding crop rather than to build up the nitrogen supply in the soil.

Discussion

The results of these experiments show that in the two-year corn — soybean rotation followed, rye, rye-and-vetch, and vetch usually gave increased yields when plowed under as green manure crops. Because of the differences in original productivity of the soil the comparison using the Method II would seem to be the most reliable.

By this method the average increases in yield of silage as reported were 0.615, 1.839, and 1.169 tons per acre from rye, rye-and-vetch, and vetch cover crops respectively over the 11-year period.

The average increases in yield of soybean hay containing 15% moisture were 0.275, 0.359, and 0.189 tons per acre for rye, rye-and-vetch, and vetch respectively. While these increases are not as large as those obtained for corn they are nevertheless of considerable importance where roughage is limited.

It is of interest to note that a rye cover crop gave larger increases in yield than did one of vetch for soybeans, but vetch gave higher yields of corn. This probably is accounted for by the fact that the vetch furnished more available nitrogen for the corn than did the rye. Since soybeans are able to take nitrogen from the air, the amount of nitrogen added was not an important factor. It has already been noted that sweet clover and crimson clover made little growth. The sweet clover heaved out of the ground during the winter on the plots and made no growth in the spring. This was true in many years also with the crimson clover cover crop. In the case of sweet clover earlier planting would undoubtedly enable the plant to make sufficient growth and establish a deep enough root system so that it would not winterkill. It is being used successfully in orchards in other sections of the state, and both crimson and sweet clover are surviving the winters at the Lakin Experiment Farm on the Ohio River.

It should also be emphasized that the increases obtained in this experiment probably are lower than might ordinarily be expected be-

cause of the fact that erosion was not a serious problem on most of the plots and also because of the fact that, during the early years of the experiment, lime and phosphate were undoubtedly deficient. After the soil had been limed and the crops regularly fertilized the increases in yield were materially larger. Cover crops alone cannot in any sense take the place of lime and fertilizer.

The rotation followed in this experiment is one which should be practiced only on land where danger of erosion is slight, and under conditions where only a limited acreage is available for the production of grain and hay crops. These conditions obtain in West Virginia on farms where there is a limited amount of level upland or bottomland. This land must then be used as often as possible for corn while the more hilly land should be kept in meadow. Where the acreage of land suitable for cultivated crops is sufficient to meet the needs of the farmer a longer rotation is desirable. In this event the crop rotation can usually be developed to maintain cover on the land throughout the year without resorting to cover crops.

Summary and Conclusions

The results of 13 years' experiments with rye, rye-and-vetch, crimson clover, and sweet clover cover crops in a corn — soybean rotation may be summarized as follows:

(1) Rye, rye-and-vetch, and vetch increased the yield of both corn silage and soybean hay. The increase was the greatest on the plots having a cover crop of rye and vetch.

(2) Crimson clover and sweet clover did not make satisfactory cover crops in this rotation at Morgantown. The winters were too severe for these crops under the conditions of this experiment.

(3) The results show only the effect due to reduction of losses by leaching and the increase in available plant nutrients. Erosion losses on slopes would undoubtedly greatly increase the beneficial effect of the cover crops.

(4) There were no significant differences in total nitrogen content of the soil at the end of the experiment. All the soils showed some decrease in total nitrogen.

Appendix

The methods used in making the statistical analysis followed those proposed by Student *(1)*. Certain modifications in pairing were necessary because of the field plan of the plots. As suggested in the text of

this paper, two methods were used in order to estimate as accurately as possible the significance of the observed differences.

Method I — The method of Student of comparing adjacent plots was followed in comparing check vs. rye, check vs. sweet clover, and rye vs. rye-and-vetch. Inasmuch as the other comparisons made were not from adjoining plots, the nearest check plot was used in the comparisons of check vs. rye-and-vetch and check vs. crimson clover. The vetch plots lay equidistant from two check plots, so the average of these plots was used in making comparisons. The difference (D) recorded in Tables 2 and 4 represents the sum of the differences divided by the number of comparisons.

Method II — The results obtained by Student's method indicated a difference in the natural productivity of the soil. Inasmuch as the effect of cover crops should be greater over a period of years than in the first year, the first crop on each plot was taken to indicate natural productivity. In the case of soybeans which were grown on both series before cover crops were planted, this method should give satisfactory results. In the corn plots one series had one cover crop turned under and the other series had two cover crops turned under before the corn was grown. However, the effect of these should be to indicate a lower value for succeeding cover crops. Thus the differences measured might be expected to be less than the actual differences. Another possibility in the analysis of the corn yields would be to compare these with the first soybean crop. However, these two crops are so different that the use of corn yields as a basis would appear to be more reliable.

The method as used in determining D was as follows: Yield of plot in any year less yield in first year will give increase or decrease due to seasonal variation and to treatment. In comparing check vs. rye the difference in any one check plot is subtracted from the corresponding difference in the adjacent rye plot. This gives the difference due to treatment. These differences are treated in exactly the same manner as in Student's method, and the significance of the differences is calculated.

Example — Corn		1922	1924	D
		Tons		
Plot 1	Check	1.89	1.07	—0.82
Plot 2	Rye	1.95	0.93	—1.02

—1.02 — (—0.82) = —.20 (Difference in favor of check for plots 1 and 2, 1924.)

The significance of differences calculated by the two methods was determined by use of the formula

$$t = \sqrt{\frac{(D)^2/N \ (N-1)}{D^2/N - (D)^2/N}}$$

From t the value of P was determined from Fisher *(2)*.

(2) Fisher, R. A. Statistical Methods for Research Workers. 1930. Oliver and Boyd, London. p. 1939.